Amendments to the Specification

1. Please replace paragraph [0004] of the application with the following amended paragraph:

[0004] Commercial semiconductor foundries often limit designers to a few choices of materials or number of structural layers in a fabricated device. As a result it may not be possible to create many specialized devices required for demanding semiconductor or Micro Electro Mechanical Systems (MEMS) applications without custom fabrication methods, methods that are usually expensive to employ. As an alternative, highly complex structures can be made by flip-chip bonding of surface-micromachined features onto a variety of other substrates or even other chips fabricated in the same process. The original often silicon host substrate is then discarded during a following release etch to provide, for example, advanced MEMS devices that are suitable for RF, microwave, or optical applications where specific material properties or additional structural layers are required.

2. Please replace paragraph [0006] of the application with the following amended paragraph:

[0006] Flip chip bonding of two integrated circuit sized component modules into a MEMS or other single device has however almost universally required each of the component modules to remain on its fabrication substrate or a substitute substrate during the bonding operation. The known few exceptions to this rule involve especially fabricated modules affording some special forms of protection for one module. The present invention changes this situation into one wherein someone with access to the most basic device fabrication capability and its tools can achieve flip chip bonded devices, including devices fabricated on two different and incompatible substrate materials and devices fabricated to include multiple MEMS modules in stacked array. Moreover, the present invention eliminates a significant difficulty in correctly aligning two substrate-mounted modules for bonding. Since the present invention allows use of simple visual alignment procedures it eliminates the need for an expensive piece of measurement-capable fabrication equipment and need for the skilled user to operate this equipment. In direct terms, the present invention is thus concerned with improved off-substrate bonding.

3. Please replace paragraphs [0024]–[0031] of the application with the following paragraphs:

[0024] These and other objects of the invention are achieved by the hinge and latch method of fabricating an electronically controlled MEMS device comprising the steps of:

[0025] forming electronic control circuit module and MEMS active element module portions of said MEMS device on first permanent and second sacrificial substrate members respectively;

[0026] said second sacrificial substrate MEMS active element module forming step including providing multiple substrate layers-resident sacrificial supplementary components comprised of a substrate hinge mounted etch plate, etch plate to MEMS active element module connection tethers, a substrate coupled etch plate latch assembly and an etch plate to sacrificial substrate anchor assembly;

[0027] releasing said MEMS active element module and selected of said sacrificial supplementary components from forming-related confinement in said substrate multiple layers into movable, hinge mounted to one of said sacrificial substrate and to other of said supplementary components, states;

[0028] rotating said released hinge mounted etch plate and tether coupled MEMS active element module combination at said hinge into a selected off of sacrificial substrate position by applying external forces to said etch plate and tethered MEMS active element module combination;

[0029] latching said etch plate and tethered MEMS active element module combination into said selected off MEMS substrate rotated position by coupling slidably movable portions of said etch plate latch assembly with said etch plate using external, latch assembly-received, forces;

[0030] disposing said MEMS active element module, said tether-attached etch plate, and said hinge mounted MEMS active element sacrificial substrate combination into a position of registered MEMS active element module engagement with said electronic control circuit module; and

[0031] engaging said MEMS active element module and said electronic control circuit module into a registered, fixed, device housing-surrounded, electronically controlled MEMS device.

4. Please replace paragraphs [0057]–[0062] of the application with the following amended paragraphs

[0057] The micromirror array 100 shown in FIG. 1 is arranged to include an 8x8 modules array of cantilever micromirror modules intended for marriage with similarly sized and compatibly disposed electronic circuit modules that may also be in array form. The present invention is of course also applicable to individual devices that are not disposed in this array form. In FIG. 1, the micromirror array 100 is attached to a hinge mechanism 102 through tethers 104 that can be severed once the array is rotated and bonded onto, for example, a CMOS receiving module array as is shown at 300 in FIG. 3. The tethers 104 may be of whatever length is needed in order to allow positioning of a MEMS module over the electronic circuit module i.e., tether 104 length is determined by the size and layout of the electronic circuit module and the need to reach across parts of this module in positioning and aligning the MEMS module.

[0058] After release, the array 100 is rotated off the edge of the chip 106 and latched into place by a slider assembly shown generally at 108 in the FIG. 2 ~~FIG. 1~~ drawing. An etch plate or release plate or protective member or shield member or header member 112 (herein primarily referred-to as an etch plate member) is used to connect the tethers 104 to the hinge mechanism 102 and serves the significant additional functions described subsequently herein. The name "etch plate" is recognized as being somewhat generic and non descriptive at first blush for the element 112, however, since one of the functions of this element is to supply structural support for a MEMS device during susceptible parts of an etching process this name is believed not altogether inappropriate. The hinge mechanism 102 is anchored to the substrate 110 of the chip 106 by a row of first hinge portions. A row of second hinge portions connects the etch plate or protective member or header members 112 to the row of first hinge portions and the substrate 110 via a hinge pin, all as described in greater detail below herein.

[0059] Notably in the FIG. 2 status, the array 100 can be metallized with reflective materials without masking or preprocessing. The array 100 is then aligned over the CMOS receiving module 300 of FIG. 3 where bonding, using for example one of a variety of conductive adhesive materials, may be accomplished. It is particularly notable that the procedure represented in FIG. 1, FIG. 2 and FIG. 3 can be completed using only a standard probe station probe element as a manipulating tool. In the identified example the final MEMS devices will consist of surface-micromachined mirror surfaces that are bonded

directly above address electrodes located over, in this instance, latching CMOS addressing circuits. Each mirror surface may be supported by compliant flexures connected to a bonding frame that surrounds it. This frame also provides uniform resting support throughout the array.

[0060] Additionally in order to better appreciate details of the present invention FIG. 4 in the drawings illustrates a single MEMS device achievable with the assistance of the invention in which a mirror surface deflects when a CMOS address cell is activated. In the FIG. 4 cross sectional view, an individual cantilever micromirror 400 and 400' (in its two operational positions) of a MEMS module 402 is disposed <u>in</u> positions enabling its control by the electrical circuits of a CMOS module 404. In the FIG. 4 illustration, the address electrode 406 of the CMOS module 404 is shown wired to the drain of some arbitrary complementary logic circuit transistor to effect this control. The electrode 406 is formed in the upper metal layer of a CMOS process and remains covered with a thin layer of oxide 408 for protection and isolation from the mirror surface. Each feature within a FIG. 4 type of device is carefully arranged with specific topographical considerations such that mating elements align properly when positioned into the FIG. 4 condition and no object interferes with the motion of any other.

[0061] In FIG. 4, the mirror 400 lower surface will actually come to rest on an area of field oxide at 412. Without the spacer layers shown under each column of the bonding frame, at 410 for example, some of the mirror 400 surfaces in an array would achieve no more than a 2 degree range of tilt. The spacer layers 410 <u>when</u> added to the MEMS module however elevate the mirror 400 enough for many devices to achieve roughly 5 degrees of tilt. The pivot point for the mirror 400 is located on the spacer layers 410 portion of the MEMS module 402 and appears at <u>413</u> ~~412~~ in FIG. 4. The FIG. 4 drawing illustrates the final disposition of the modules 402 and 404 in a MEMS device preferably following use of the present invention in achieving this disposition. The present invention is of course not limited to micromirror devices as shown in FIG. 4 but can relate to most MEMS device types.

[0062] FIG. 5 in the drawings includes the vertically aligned views of FIG. 5a, FIG. 5b and FIG. 5c and shows details previously recited and additional details relevant to the present invention. Identification numbers appearing in the FIG. 5 drawings and the other drawings herein repeat those used in FIG. 1 through FIG. 4 to the best degree possible; in other words, element identification numbers remain consistent in the drawings of the

present document once assigned, to the best degree possible. New identification numbers including the drawing FIG. number in the hundreds digit position are assigned in FIG. 5 and the ensuing drawings as are needed in the related discussion.

5. Please replace paragraphs [0064]–[0068] of the application with the following amended paragraphs:

[0064] The MUMPS process and its two oxide-separated polysilicon layers is in reality a desirably simple and inexpensive process in comparison with for example the SUMIT process which provides up to four releasable layers of semiconductor material. The SUMIT process is known by the more complete name of Sandia Ultraplanar Multi-level MEMS Technology and is available from Sandia National Laboratories at Kirtland Air Force Base in Albuquerque, New Mexico, http://mems.Sandia.gov/scripts/index.asp. Either the SUMIT or the MUMPS process or another process of these natures as is known in the art may be used with the present invention. It is especially notable that even a relatively simple and two layer process such as MUMPS may be enhanced significantly by way of the present invention since the invention easily supports an arrangement wherein multiple MEMS modules are fabricated on the same or on different substrates and are then stacked on top of each other during the bonding process of a MEMS device. In this manner, the present invention enables the fabrication of a complex MEMS device of 2, 4, 6, 8 or more layers or even any number, N, layers while using merely a simple and inexpensive, even two layered, fabrication process. The complexity of the fabricated MEMS device can be enhanced significantly by this access to a greater number of releasable layers during fabrication.

[0065] In the FIG. 7 drawing, the clevis element of a hinge appears at 702 and a contoured form of a pin element appears at 700. The wings 704 and 706 in the FIG. 7 hinge attach the clevis element to a substrate member while the pin element 700 attaches to a hinge-anchored rotating element. Thus the FIG. 7 hinge is a reverse arrangement of the hinge portions appearing in the FIG. 5 drawing. A hinge of similar arrangement to that of the FIG. 5 and FIG. 7 hinge is additionally disclosed in the U.S. Patent 5,994,159 of V.A. Aksyuk et al. and also in the U.S. Patent 6,300,156 of H.L. Decker et al.; patents that are hereby incorporated by reference herein. Notably the Aksyuk et al. and the Decker et al. patents involve the erection of pseudo three-dimensional structures on the surface of a MEMS device rather than the rotated, sacrificial substrate-free, processing of a MEMS module.

[0066] In actually each of the hinge elements appearing in the FIG. 5 and the FIG. 7 drawings is comprised of polysilicon in a MUMPS process device. According to this arrangement, each of the clevis and wings 702, 704, 706 are portions fashioned by etching from a single upper layer of polysilicon, i.e., a Poly-2 layer while the pin element 700 is part of a lowermost and first deposited lower Poly-1 layer of polysilicon. These two layers of polysilicon are originally separated by an etch-responsive layer of oxide material that initially fills the interior of the clevis 702 between polysilicon layers until it is removed in a controlled etching sequence to free the pin 700 into the illustrated rotatable condition. During fabrication of the polysilicon layers once the polysilicon 1 hinge pin 700 is formed the oxide layer and the overlying polysilicon 2 layer conform to its shape and thus form the shape of the clevis 702. Notably the uppermost or Poly-2 of the two polysilicon layers is not required to completely surround the pin element 700 in order to achieve the FIG. 7 hinge; the lower portion of the clevis 702 is in reality supplied by the substrate of the device. The two polysilicon layers of the MUMPS process are in actually also sufficient to form each of the other MEMS module elements shown in the FIG. 5 drawing as is noted in appropriate locations of the following paragraphs of description.

[0067] The etch plate 112 is fabricated with initial tether connections to the anchor member 516 shown in FIG. 5a and FIG. 5c. According to this arrangement, the etch plate remains captured in its connection with the substrate 110 notwithstanding removal of the oxide layer (or layers) that originally hold it captive, i.e., oxide layers removed during the course of normal fabrication of the MEMS module. As this statement implies, the present invention can be fabricated in structural layers of a device that are elsewhere needed; the addition of layers for present invention purposes is thus not necessary.

[0068] Tethered release of the etch plate into a rotatable condition in the FIG. 5 apparatus is therefore a fully controllable event that may be initiated at a convenient point in the fabrication process following the oxide etching event, a point in fact preferably selected to be late in the processing and after release of the array 100. Remainder portions of the tether elements used to accomplish this retention and release of etch plate 112 from substrate anchor element 516 appear at both 518 and 520 in the FIG. 5c drawing. These remaining portions are joined in the FIG. 5a pre-rotation condition of the MEMS device and are severed by a burn-through electrical current or physical rupture or by laser burning in the manner of the tethers 104 as described elsewhere herein. In the FIG. 5a pre release condition the joined tethers at 518 and 520 (in FIG. 5c) oppose the uplifting force of the

lifting beams 508 and 510. Notably processing of the FIG. 5 modules can be accomplished by way of conventional non-rotating flip-chip processing techniques by omitting the severing of tethers 518 and 520 and thus maintaining the MEMS module in the FIG. 5a condition if desired. Cross sectional details of the substrate anchor element connecting with tethers 104 are shown in the FIG. 6a drawing.

6. Please replace paragraph [0076] of the application with the following amended paragraph:

[0076] The FIG. 5b gap, 536, preferably is made of a shorter length than the tongue 514 in order to prevent damage to the tongue 514 and the etch plate 112 from inadvertent excessive rightward movement from the probe tip 528 engagement. According to this arrangement the two slider portions meet at 540 in FIG. 5b before damage to the tongue 514 can occur. Lengths of 45 micrometers and 50 micrometers for the gap 536 and the tongue 514 are found to be satisfactory for this damage limiting purpose. The remainder parts 532 and 534 of the pentagonal shaped slider portion 524 are actually substrate-attached guide rails serving both to hold the slider assembly in a captive substrate-parallel condition and to prevent inadvertent movement of the slider assembly 105 in the leftward direction by the probe tip 528. The cross sectional shape of the remainder parts 532 and 534 are shown in the drawing of FIG. 6b where the sliding but capturing nature of the remainder parts 532 and 534 also appears. The FIG. 5b and FIG. 5c, thin rectangular patterns at 538 in the slider assembly represent dimples resulting from formation of elongated sliding feet 537 as are more visible in the FIG. 6d drawing. The space immediately below the feet 537 in FIG. 6d is of about one-half micrometer thickness and is preserved during the deposition process by the presence of a later removed oxide layer.

7. Please replace paragraph [0079] of the application with the following amended paragraph:

[0079] With the FIG. 5 anchor tethers cut, the lifting beams 508 and 510 provide sufficient elevation such that arrays may be easily rotated off the edge of the module in the presence of methanol fluid resistance during a release rinse. Care is however needed when removing the substrate free MEMS module structure from a rinse bath to avoid surface tension damage to delicate elements. After removal from the rinse, the arrays can then simply be dried in air rather than using a critical point dryer since they no longer rest above a substrate that would ordinarily damage mirror surfaces or other structure as

methanol or another rinse agent evaporates. The lifting beams 508 and 510 appear in cross sectional representation in the FIG. 6a drawing where a metallic gold layer is shown at 600, 602 and 604 and this gold is shown to overlay a Poly-1 layer.